National Aeronautics and Space Administration

Cutting edge

Goddard's Emerging Technologies

And the Winner Is....

Volume 9 | Issue 1 | Fall 2012

in this issue:

Innovator of the Year, Stephanie Getty (Photo Credit: Chris Gunn)

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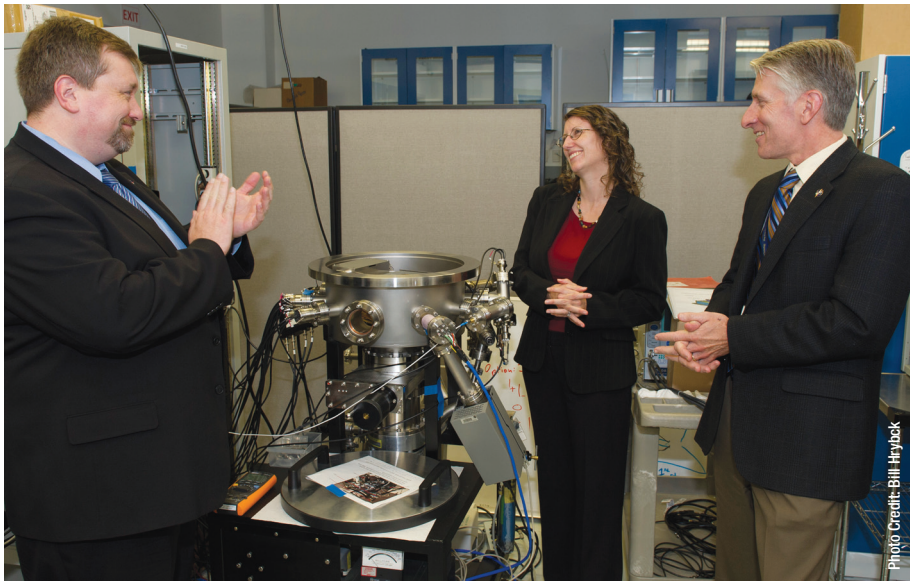
Getty Wins Goddard's Top R&D Prize

Goddard's Office of the Chief Technologist has selected Goddard technologist Stephanie Getty as its 2012 "Innovator of the Year." The annual award, which the organization launched in 2007, is given to those who exemplify the best in innovation.



Technologist Stephanie Getty reacts to the news delivered by Goddard Chief Technologist Peter Hughes (right) that she had been selected as this year's "Innovator of the Year." She had just finished explaining her technology to NASA Chief Technologist Mason Peck (left), who was visiting the center that day.

"Each year, it gets harder selecting the one person who epitomizes the finest in NASA research and development," said Goddard Chief Technologist Peter Hughes. "However, our team concluded that Stephanie truly personifies the attributes that make our Internal Research and Development program among the Agency's most effective. She demonstrates the rare ability to leverage her ideas with other R&D successes to create wholly new instrument concepts — the quintessential definition of innovation."

Materials and Miniaturization

Since joining Goddard in 2004, Getty has focused her research on using new materials and other miniaturization techniques to develop critical instrument components, including a miniaturized electron gun to ionize gas molecules so that a spectrometer can measure their masses and a chemical field effect transistor to analyze liquids on planetary bodies.

Because of her expertise in physics and advanced materials fabrication, she also has become the go-to technologist for manufacturing carbon nanotubes, tiny hollow tubes made of pure carbon that can be grown as a thin coating or pattern. The material now is being applied to a number of Goddard instrument-development efforts because of its unique properties, (*CuttingEdge*, Winter 2012, Page 6), Hughes added.

Although Getty has applied her skills to a number of technology-development efforts, she began focusing in recent years on one goal in particular. "I knew I wanted to take the devices I developed to gather measurements that would support planetary science," she told *CuttingEdge*.

In 2012, her wide-ranging research efforts paid off.

She received $2.2 million in NASA follow-on funding to advance two new instrument concepts. One, funded by NASA's Planetary Instrument Definition and Development Program, is a two-step laser tandem mass spectrometer capable of detecting a wide range of organic compounds in complex mixtures (*CuttingEdge*, Summer 2012, Page 5).

Under her most recent award from NASA's Astrobiology Science and Technology Instrument Development program, Getty and her team will develop an instrument for remotely analyzing organic materials, including amino acids, on comets, asteroids, and the icy moons in the outer solar system (see related story, page 3). Both instruments borrow heavily from the instrument components she devised under her Goddard Internal Research and Development program awards.

"Stephanie is an innovator," said Anne Kinney, Solar System Exploration Division director. "She does an excellent job of coming up with new and interesting approaches to planetary technology. The fact that she has won two NASA technology proposals in the same year is a testament to her ability to think outside of the box and demonstrates her top-notch proposal-writing skills." ❖

The Hunt for Amino Acids

Winner of Top Innovation Award Wins Follow-On Funds to Develop OASIS

Stephanie Getty and her research associate, Adrian Southard, prepare one of OASIS's instrument components, an electrospray nozzle, for characterization testing. The component converts liquid samples to gas-phase ions and is, in essence, the interface between the liquid chromatograph and the mass spectrometer.

The hunt for the organic molecules that create proteins and enzymes critical for life here on Earth has largely happened in sophisticated terrestrial laboratories equipped with high-tech gadgetry needed to tease out their presence in space rocks and other extraterrestrial samples.

A Goddard technologist now wants to take that search to the sources themselves.

Stephanie Getty has won $1.2 million from NASA's Astrobiology Science and Technology Instrument Development (ASTID) program to advance the Organics Analyzer for Sampling Icy Surfaces (OASIS), a miniaturized liquid chromatograph-mass spectrometer that leverages technologies developed under previous Goddard-sponsored R&D efforts to study the chirality, or "handedness," of amino acids on the icy moons of the outer planets, asteroids, and Kuiper Belt Objects.

"It's like we're packing up a well-equipped Earth lab and flying it to an asteroid or another solar system body, where we can get access to a pristine supply of these organic molecules to study," Getty said, adding that by going to the source, scientists reduce the risk of contaminating samples with Earth-borne compounds. "With an instrument like OASIS, we could get that much closer to understanding how organic chemicals formed in the solar system, whether the potential for life exists elsewhere, and what may have seeded life here on Earth."

And OASIS would carry out this science with 100 times greater sensitivity than what was possible with previously flown liquid chromatograph-mass spectrometers, she added.

Why Amino Acids?

The hunt for amino acids in extraterrestrial sources began 50 years ago when scientists discovered a variety of non-terrestrial amino acids in meteorites, remnants of asteroids that had fallen to Earth.

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839 Planets and Counting

Scientist Pursues New Spectrograph for Characterizing Earth-Like Planets

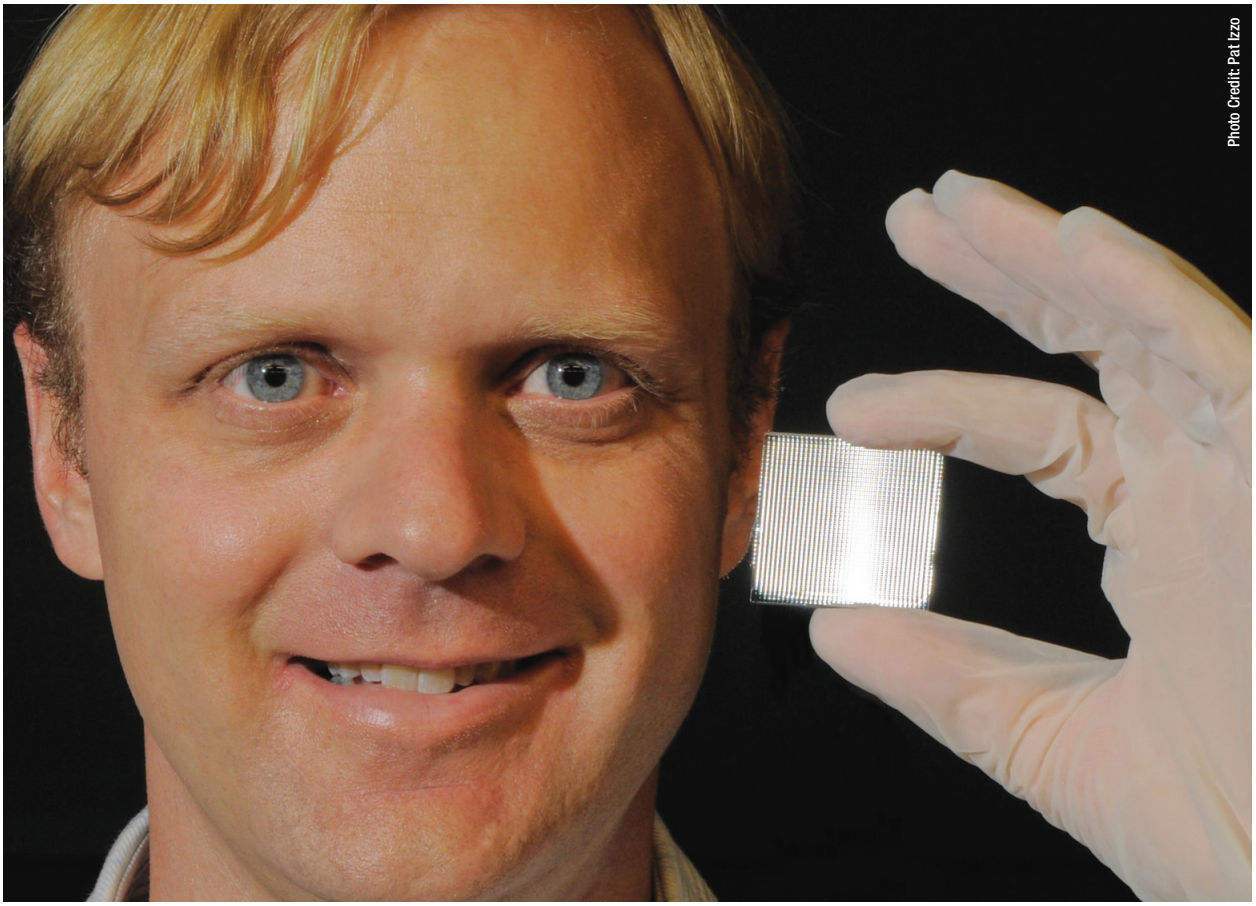

Photo Credit: Pat Izzo

Goddard scientist Michael McElwain holds a new lenslet array, a critical component in a spectrograph he's developing to image and characterize an Earth-like planet beyond our solar system.

Since scientists discovered the first extrasolar planet in 1995, the number of confirmed finds mainly through indirect observation now stands at 839, and of that number, six are potentially habitable. However, no one has yet to directly image an Earth-like planet, let alone analyze its light to find molecular oxygen, the stuff we Earthlings breathe.

Goddard scientist Michael McElwain is now advancing an instrument that could help make that find if coupled to a powerful telescope equipped with starlight-suppression technology.

"Direct observation of an Earth-like exoplanet is exceedingly difficult since it's about 10 billion times fainter than the star it orbits," McElwain said. Given the extreme challenge, NASA now is funding several teams to advance competing high-contrast light-suppression systems to block the starlight and make it easier to discern a small planet. Goddard scientist Rick Lyon heads one of those teams and is advancing a concept called the visible nulling coronagraph (*CuttingEdge*, Spring 2012, Page 4).

Also needed, however, is an instrument capable of both imaging an Earth-like planet and analyzing its light to uncover the existence of chemical compounds, like molecular oxygen, that could indicate the presence of life, he said. Except for him, "there is no other NASA center working on a high-contrast imaging instrument," McElwain added.

Integral Field Spectograph Holds Key

McElwain's proposed instrument is an integral field spectrograph (IFS), a 3-D-type device that can gather spectra at every spatial element in its field of view. Although IFS-type instruments are used in ground-based observatories, including the Keck Observatory in Hawaii, current state-of-the-art models cannot achieve the challenging

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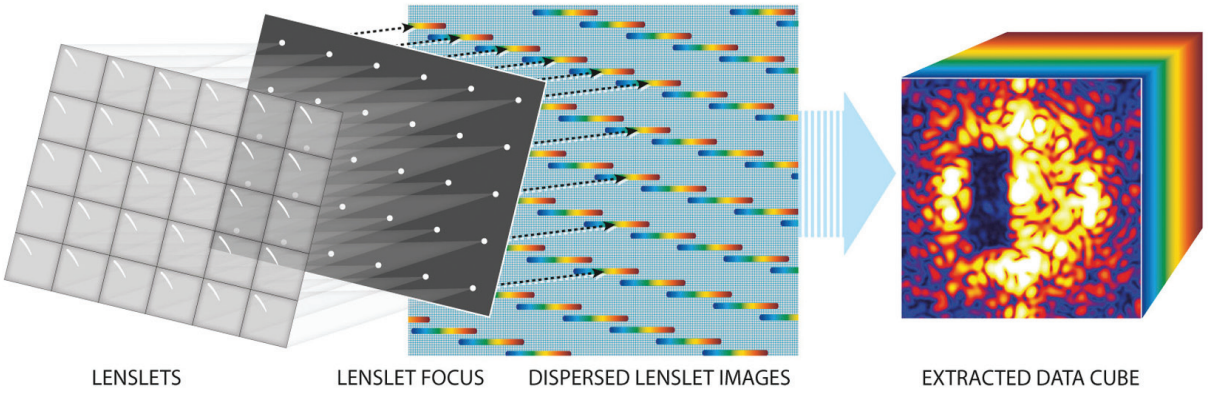

This graphic shows how the lenslet array and the pinhole mask in a new integral field spectrograph work together to focus and contain light. After the light passes through the spectrograph's optics, a spectrum for every spatial element in the instrument's field of view is produced.

performance requirements needed for imaging and obtaining spectral measurements of Earth-like planets light-years away, McElwain said.

Indeed, extracting spectroscopic data from a distant planet is tricky business. The light of a host star dwarfs that of the exoplanet. But as long as scientists can get a pinprick of light, they can measure the different wavelengths of light emanating from that object's atmosphere to learn more about its formation and evolution, and perhaps discover the presence of atoms and molecules that could indicate signatures of life.

"The spectral imager Mike is developing will provide this capability," said Karl Stapelfeldt, chief of Goddard's Laboratory for Exoplanets and Stellar Astrophysics. "It is on the critical path realizing the age-old goal of finding and characterizing Earth-like planets around nearby stars."

PISCES Designed

With funding from Goddard's Internal Research and Development (IRAD) program and NASA's prestigious Nancy Grace Roman Technology Fellowship, McElwain has designed a tabletop-size laboratory instrument called the Prototype Imaging Spectrograph for Coronagraphic Exoplanet Studies (PISCES). Not only would PISCES serve as the camera on the Jet Propulsion Laboratory's (JPL) High-Contrast Imaging Testbed — a facility JPL is building to test the candidate starlight-suppression technologies — it also would serve as the foundation for a future spaceflight instrument.

However, more work needs to be done to retire risks on one especially important component — the lenslet array that focuses incoming light and directs it to a spectrograph. McElwain now is using FY13 IRAD funding to fine-tune the design of this two-inch array made up of 352 tiny individual glass segments no larger than the width of three human hairs. These lenses, which are scallop-shaped much like your eye when viewed on its side, will focus 90 percent of the incoming light to a specific point at the focal plane. The other 10 percent is diffracted outside the core.

He also plans to develop a pinhole mask — a component literally pocked with tiny holes — that would be situated behind the lenslet array to block the diffracted light from entering the spectrograph and contaminating the resulting spectral measurements, which are gathered for every spatial element in the instrument's field of view. The multiple spectra are combined into a data cube that can be analyzed for the existence of life-sustaining chemicals.

"We've never used this type of pinhole mask. This is new," McElwain said.

With the IRAD funding, McElwain plans to advance the array's readiness level from two to four, making the concept an attractive candidate for NASA follow-on funding from the Technology Development for Exoplanet Missions program. If all goes as planned, McElwain, expects to deliver PISCES to JPL's testbed sometime in 2015. He also expects the effort to put him in good stead to win a berth on a future planet-finding mission.

"This instrument has great potential for finding habitable planets," he said. "This is our path forward." ❖

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Fast Forward to the Past

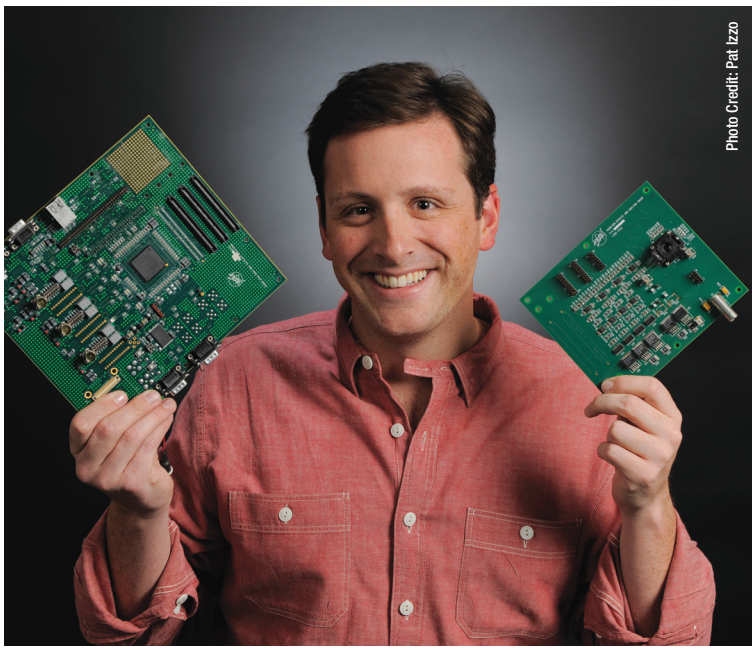
Technologist to Test 'Game-Changing' Data-Processing Technology

It's a digital world. Or is it?

Goddard technologist Jonathan Pellish isn't convinced. In fact, he believes a computing technology of yesteryear could potentially revolutionize everything from autonomous rendezvous and docking to remotely correcting wavefront errors on large, deployable space telescope mirrors like those to fly on the James Webb Space Telescope (JWST).

"It's fast forward to the past," Pellish said, referring to an emerging processing technology developed by a Cambridge, Massachusetts-based company, Analog Devices Lyric Labs.

So convinced is he of its potential, Pellish is meeting with scientists and engineers to explain the technology's capabilities and is using FY13 NASA Center Innovation Fund resouces to build printed circuit boards that researchers can use to test the technology's performance for a range of scientific applications. He also has carried out preliminary radiation-effects studies to see how the technology's architecture holds up under the extreme environment encountered in space.



Jonathan Pellish holds in his right hand a Goddard-developed digital test board. In his left hand is the IRAD-developed daughter card containing the analog-based data-processing integrated circuit. The daughter card snaps into the digital test board and will be used to test a number of spaceflight processing applications.

"I wouldn't do it unless I really believed in it," Pellish added. "This is one of the few things I've seen that is really different than what others are trying to do. I think this technology could fundamentally change the way we carry out onboard processing."

Analog-Based Microchip

The new technology is an analog-based microchip developed with significant support from the Defense Advanced Research Projects Agency (DARPA). Instead of relying on tiny switches or transistors that turn on and off, producing streams of ones and zeros that computing systems then translate into something meaningful to users, the company's new microchip is more like a dimmer switch. It can accept inputs and calculate outputs that are between zero and one, directly representing probabilities, or levels of certainty.

"The technology is fundamentally different from standard digital-signal processing, recognizing values between zero and one to accomplish what would otherwise be cost prohibitive or impossible with traditional digital circuits," Pellish said.

The processor's enhanced performance is due to the way the technology works, he explained. While digital systems use processors that step through calculations one at a time, in a serial fashion, the new processor uses electronic signals to represent probabilities rather than binary ones and zeros. It then effectively runs the calculations in parallel. Where it might take 500 transistors for a digital computer to calculate a probability, the new technology would take just a few. In other words, the microchip can perform a calculation more efficiently, with fewer circuits and less power than a digital processor — attributes important for space- and power-constrained spacecraft instruments, Pellish said.

Although "there has been an overwhelming amount of positive support for the technology within Goddard" since Pellish began introducing colleagues to its capabilities, he is the first to concede that the technology isn't appropriate for all space applications.

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Fast Fourier Transform

Because of its efficiency and inherent design, however, it's especially ideal for computing fast Fourier transforms (FFTs), and more particularly the discrete Fourier transform, a ubiquitously used mathematical algorithm in digital-signal processing. Among other things, Fourier transforms decompose signals into their constituent frequencies and are used to generate and filter cell-phone and Wi-Fi transmissions as well as compress audio, image, and video files so that they take up less bandwidth.

Among other products, the company has developed an analog-based integrated circuit geared specifically for computing Fourier transforms. The team will use the technology, which the company donated, to assemble several custom circuit boards. "We'll take the hardware and see what it can do with our data and applications," Pellish explained.

One of the first applications the group plans to target with a version of the FFT integrated circuit is wavefront sensing and control, the computational technique for aligning multiple mirror segments, like those that are flying on JWST, so that they operate as a single mirror system.

In addition, Jeffrey Klenzing, who works with Goddard's Space Weather Laboratory, wants to evaluate the technology's use for onboard data processing, particularly for studies of the Sun. "For a typical sounding rocket application, we send all data down and perform fast Fourier transforms on the ground. However, for satellite missions, this is not feasible given limited telemetry," Klenzing said, in a letter supporting Pellish's FY13 proposal. "A chip for performing rapid, reliable FFTs would be very useful for such heliophysics missions particularly with the push toward smaller, low-power satellites such as CubeSats and nanosats."

Pellish also believes autonomous rendezvous and docking and other applications requiring precise locational information would benefit from the analog-based technology. "We're trying to create a new market at NASA for analog processing. I believe it will give us a competitive edge. If we can push this, it could revolutionize how we do onboard data processing." ❖

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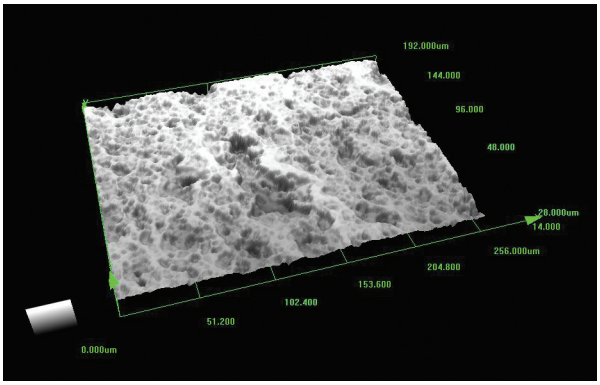
Ah, That New Car Smell

Goddard Technology Protects Spacecraft from Outgassed Molecular Contaminants

For some people, the best part about buying a new car is its factory-fresh new car smell — a distinctive aroma created when the chemicals and residual solvents used to manufacture dashboards, car seats, carpeting, and other vehicle appointments outgas and fill the cabin.

While the scent may be alluring to some, many researchers believe exposure to these gases isn't particularly healthy — so unhealthy, in fact, that some recommend that drivers keep their new cars ventilated while driving.

As it turns out, outgassed solvents, epoxies, lubricants, and other materials aren't especially wholesome for contamination-sensitive telescope mirrors, thermal-control units, high-voltage electronic boxes, cryogenic instruments, detectors, and solar arrays, either. As a result, NASA engineers are always looking for new techniques to prevent these gases from adhering to instrument and spacecraft surfaces and potentially shortening their lives.



This is a close-up view of the highly porous, sprayable coating that Goddard technologists created to attract and then trap outgassed contaminants that harm spacecraft components.

A group of Goddard technologists has used Goddard Internal Research and Development program funding to create a low-cost, easy-to-apply solution, which is more effective than current techniques.

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Led by Principal Investigator Sharon Straka, the team has created a new, patent-pending sprayable paint that adsorbs these gaseous molecules and stops them from affixing to instrument components. Made of zeolite, a mineral widely used in industry for water purification and other uses, and a colloidal silica binder that acts as the glue holding the coating together, the new molecular adsorber is highly permeable and porous — attributes that trap the outgassed contaminants. Because it doesn't contain volatile organics, the material itself doesn't cause additional outgassing.

"It looks promising," Straka said. "It collects significantly more contaminants than other approaches."

Goddard technologist Nithin Abraham, a member of the team that has developed a low-cost, low-mass technique for protecting sensitive spacecraft components from outgassed contaminants, studies a paint sample in her laboratory.

Advantages Over Current Techniques

Instrument developers currently use zeolite-coated cordierite devices that look like hockey pucks. Because each individual puck has limited adsorbing capabilities, instrument designers must install multiple units, which require complex mounting hardware. "These devices are big, heavy, and chunky and take up a lot of real estate," explained Co-Principal Investigator Mark Hasegawa.

The new paint, however, overcomes these limitations by providing a low-mass alternative. Because technicians can spray the paint directly onto surfaces, no extra mounting equipment is necessary. In addition, technicians can coat adhesive strips or tape and then place these pieces in strategic locations within an instrument, spacecraft cavity, or vacuum system, further simplifying adsorber design. "This is an easy technology to insert at a relatively low risk and cost. The benefits are significant," Hasegawa added.

Since its development, Northrop Grumman, the European Space Agency, the Laboratory for Atmospheric and Space Physics at the University of Colorado at Boulder, and Spica Technologies, a New Hampshire-based company that tests and measures optical components, have expressed interest in using the material, Straka said. NASA's ICESat2 ATLAS project is evaluating its use, pending the outcome of additional tests. Goddard scientist Ed Wollack also has begun assessing its use as a far-infrared radiation and contamination adsorber, she said.

The team plans to tweak its recipe to enhance the paint's performance and experiment with different pigments — mainly black — to create a coating to absorb stray light that can overcome the light scientists actually want to gather. She also believes the technology could be used on the International Space Station or future space habitats to trap pollutants and odors in crew quarters.

"We're ready for primetime. The coating is undergoing qualification tests and is ready for infusion into flight projects or ground vacuum systems," Straka said. ❖

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PROFILE

On occasion, CuttingEdge profiles people who are making a difference promoting and advancing Goddard technology. In this issue, we focus on Lola Fatoyinbo-Agueh, who recently received the Presidential Early Career Award for Scientists and Engineers, a coveted award given to early-career researchers who are advancing America's future in science and engineering.

Seeing the Forests AND the Trees

Goddard Scientist Receives White House Honor

Goddard scientist Temilola "Lola" Fatoyinbo-Agueh had a good reason for not answering the emails telling her that she'd just won one of the U.S. government's highest honors in science and engineering — she'd just given birth to her son.

"I just didn't believe it, I was like this can't be true," she said, recalling the moment she learned the news.

Fatoyinbo-Agueh is one of only six people at NASA to receive the 2012 Presidential Early Career Award for Scientists and Engineers, an award the White House bestows annually on researchers who show great promise advancing America's future in science and engineering. Fatoyinbo-Agueh's nomination and selection were in large part due to her work developing a first-of-its-kind radar system, called EcoSAR, for measuring the height, density, and the extent of trees in forests.

Closing the Gap

Her instrument, which she is developing under NASA's Instrument Incubator Program managed by the Earth Science Technology Office, will help close the gaps in scientists' understanding of the carbon cycle. In particular, the remote-sensing radar system will measure forest biomass, a calculation crucial to researchers' ability to determine the amount of carbon stored in those forests. These measurements are a key part of a United Nations program known as REDD+, which stands for Reducing Emissions from Deforestation and Forest Degradation.

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Lola Fatoyinbo-Agueh recently won the White House Presidential Early Career Award for Scientists and Engineers, a prestigious award she received in part because of her work on an innovative radar system for measuring biomass.

The Graphene Portfolio Expands

Goddard Investigates Two New Applications for Trailblazing Technology

Photo Credit: Pat Izzo

Goddard technologist Mahmooda Sultana is investigating two new applications for graphene, a trailblazing technology with unique physical characteristics that make it ideal for all types of spaceflight uses.

Tiny sensors — made of a potentially trailblazing material heralded as the "next best thing" since the invention of silicon — are now being developed to detect trace elements in Earth's upper atmosphere and structural flaws in spacecraft.

Technologist Mahmooda Sultana, who joined NASA two years ago and has since emerged as Goddard's go-to expert in the development of graphene-based technology, has expanded her portfolio to include two new research and development efforts aimed at creating nano-sized detectors that could detect atomic oxygen and other trace elements in the upper atmosphere and structural strains in everything from airplane wings to spacecraft buses.

"The cool thing about graphene is its properties," said Jeff Stewart, the acting assistant chief for technology for Goddard's Mechanical Systems Division. "It offers a plethora of possibilities. Frankly, we're just getting started."

Graphene, first discovered in 2004 by Russian-born scientists Andre Geim and Konstantin Novoselov, is just one atom thick and composed of carbon atoms arranged in tightly bound hexagons best visualized as atomic-scale chicken wire. Two hundred times stronger than structural steel, it not only is the strongest material ever measured, but also the most sensitive and stable at extreme temperatures, making it ideal for all types of uses. Since its discovery, hundreds of organizations worldwide have launched research efforts to take advantage of the material's unique properties.

Goddard is one in the growing contingent.

More than a year ago, Sultana and her team won R&D funding to advance graphene-based transparent conductive electrodes for large detector arrays (*Goddard Tech Trends*, Summer 2011, Page 3). Due to the team's progress setting up production facilities and fine-tuning processing techniques using chemical vapor deposition (CVD) — a

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technique for fabricating thin films — the group has succeeded at manufacturing and processing relatively large, high-quality pieces of graphene.

As a result, the group says it's ready to apply its expertise to advance other applications. "One of the most promising applications of this material is as a chemical sensor," Sultana said.

Chemical Sensors

She has teamed with retired Goddard scientist Fred Herrero, who is pursuing the research in an emeritus capacity, to develop a miniaturized, low-mass, low-power, graphene-based detector that could measure the amount of atomic oxygen in the upper atmosphere. This reactive element, which doesn't exist naturally in Earth's atmosphere for very long, is highly corrosive. As satellites fly through the upper atmosphere, the chemical strikes them at about five miles per second. The impacts destroy commonly used spacecraft materials, such as Kapton.

Although scientists believe atomic oxygen makes up 96 percent of the thin atmosphere in low-Earth orbit, Herrero is interested in measuring its density and determining more precisely its role in creating atmospheric drag, which can cause orbiting spacecraft to lose altitude prematurely and plunge to Earth. "We still don't know the impact of atomic elements on spacecraft in creating a drag force," he said. "We don't know how much momentum is transferred between the atom and the spacecraft. This is important because engineers need to understand the impact to estimate the lifetime of a spacecraft and how long it will take before the spacecraft reenters Earth's atmosphere."

"We still don't know the impact of atomic elements on spacecraft in creating a drag force. We don't know how much momentum is transferred between the atom and the spacecraft. This is important because engineers need to understand the impact to estimate the lifetime of a spacecraft and how long it will take before the spacecraft reenters Earth's atmosphere."

— Fred Herrero

Research has shown that graphene-based sensors offer a good solution, Sultana said. When graphene absorbs atomic oxygen, it oxidizes, producing a change in the material's electrical resistance that a graphene-based sensor could then quickly count to produce a more accurate density measurement. "I'm really excited about this material's possibilities," Herrero said, adding that graphene would greatly simplify the steps needed to measure atomic oxygen. "We'd be counting how often the resistance changes."

Atomic oxygen isn't the only element the chemical sensor could measure, Sultana said. She also believes it's ideal for measuring methane, carbon monoxide, and other gases on other planetary bodies and monitoring outgassing that sometimes contaminates instrument optics (see related story, page 7). She plans to fabricate and test the first generation of graphene-based chemical sensors by the end of the fiscal year, she said. "This is very, very early stage," Sultana added.

Strain Detection

Graphene's unique attributes also make it a viable candidate for detecting stresses in spacecraft components, she said. With her collaborators at the Massachusetts Institute of Technology (MIT), the team is using support from NASA's Office of the Chief Technologist to advance a small sensor that could be embedded in spacecraft materials, including composites. If the material underwent some type of stress, the tiny sensors would detect it.

The team has used CVD to manufacture and test a large piece of graphene, whose electrical properties are sensitive to detecting stresses, Sultana said. Her MIT collaborators now are fabricating graphene devices and her team is wiring them to read out measurements — much like the medical electrodes used for certain medical tests. However, Sultana plans to eliminate the wiring so that it operates autonomously, she said.

"This could be deployed in a non-invasive way," Stewart said. "Right now, we use relatively large devices to detect damage or potential sources of failure, but with autonomous graphene-based sensors our hope is that we could put them into the material itself."

"We can employ a different combination of its extreme properties and use the same material for different sensing applications," Sultana added. "That's the beauty of graphene." ❖

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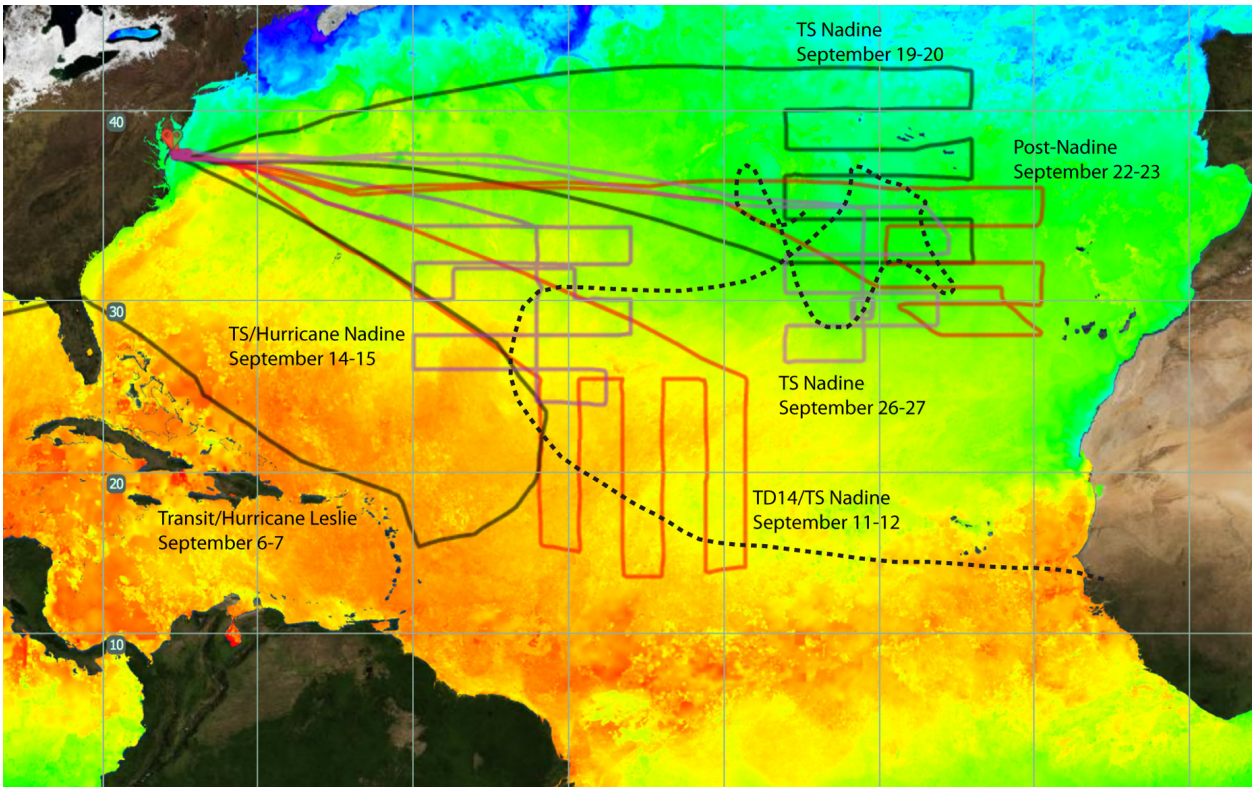
Like a Bad Penny

Long-Lived Hurricane Nadine Puts NASA Hurricane Mission Through the Paces



NASA's Global Hawk flew five science missions into Tropical Storm/Hurricane Nadine. It also circled around the east side of Hurricane Leslie during its transit flight to the Wallops Flight Facility before the hurricane mission began. This is a composite of the ground tracks of the five science flights and the transit flight. TD means tropical depression; TS means tropical storm.

Hurricane Nadine was like a bad penny; she kept showing up.

But her never-say-die persistence, which made her one of the top 50 longest-lasting tropical storms in either ocean, was good news for a team of Goddard and other scientists who packed a Global Hawk unmanned aircraft with state-of-the-art instruments just to study how storms like her intensify into full-blown hurricanes.

Nadine certainly didn't disappoint.

Researchers with NASA's Hurricane and Severe Storm Sentinel (HS3) investigation, a five-year, Goddard-managed mission dedicated to gathering difficult-to-obtain measurements of wind speeds, temperature, humidity, and aerosol concentrations in the environment surrounding the storm and the rain and wind patterns occurring inside, had a crack at her five different times.

"Interesting Lifecycle"

Over the course of her 21-day lifetime, which began September 11 when she became the fourteenth tropical system of the 2012 Atlantic Ocean hurricane season, Nadine strengthened to hurricane status a couple of times, only to weaken back into a tropical storm. "She had an interesting lifecycle," said HS3 Mission Principal Investigator Scott Braun. "There are definitely some interesting things we can learn from her."

The month-long HS3 mission, which the team flew out of the Wallops Flight Facility on Virginia's Eastern Shore, featured one Global Hawk aircraft loaded with three autonomously operated instruments that sampled the environment in which Nadine was embedded.

Installed inside the high-flying, long-duration Global Hawk were the Cloud Physics Lidar, a Goddard-

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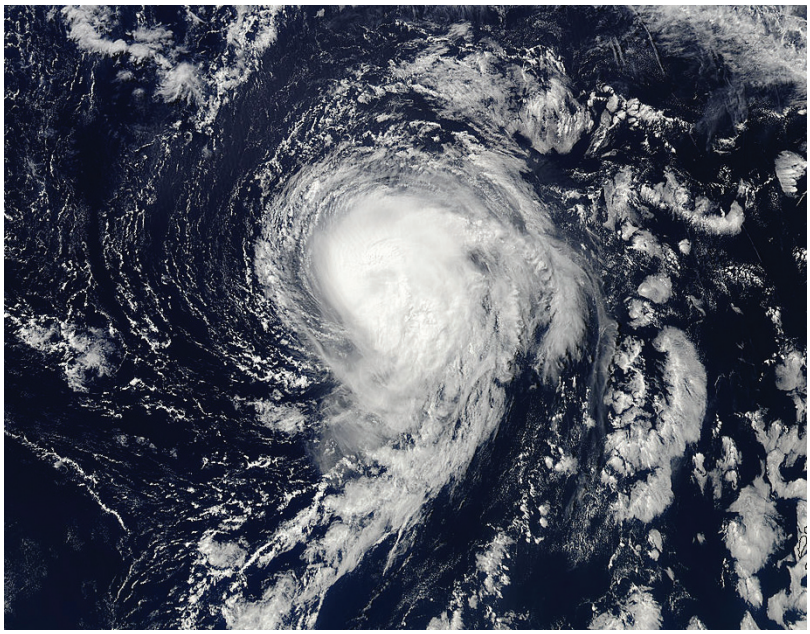
developed laser system that measured cloud structures and aerosols by bouncing laser light off these elements, and a dropsonde system provided by the National Center for Atmospheric Research and the National Oceanic and Atmospheric Administration. This system dropped small parachute-equipped sensors into the storm to measure winds, temperature, pressure, and humidity. The University of Wisconsin at Madison provided the third payload, the Scanning High-resolution Interferometer Sounder that measured the vertical profile of temperature and water vapor.



When NASA's Aqua satellite passed over Nadine on September 28, the MODIS instrument captured this visible-light image of the storm. Nadine had just regained hurricane status, with maximum sustained winds near 75 mph.

During the early stages of Nadine's development, the scientists sought data aimed at ultimately answering whether Nadine ingested the hot, dry, and dusty air associated with the Saharan air layer, which typically crosses westward over the Atlantic Ocean and potentially affects tropical-cyclone formation and intensification.

Too Early to Reach Conclusions

Although it's still too early to reach any conclusions, Braun said initial data showed that on the day she began forming about 1,210 miles east of the Lesser Antilles, she was interacting with the Saharan air and continued to do so even after she had begun moving in a northwesterly direction. Two days later, she had "strengthened from a tropical storm to a hurricane despite being hit by very strong westerly winds at upper levels and very dry air on its periphery," Braun said.

It wasn't to last, however. By September 19, Nadine had weakened to tropical-storm strength, but both the Global Hawk and NASA's Tropical Rainfall Measuring Mission satellite noticed that she had continued to display tropical characteristics, indicating that she had not transitioned into an extra-tropical storm — one that loses its tropical characteristics, such as when the core of the storm changes from a warm core to a cold core, like a typical mid-latitude low-pressure system associated with weather fronts. At that time, Nadine was located a few hundred miles southwest of the Azores Islands in the northeastern Atlantic Ocean.

Just after the Global Hawk's fifth investigation on September 26 and 27, Nadine had re-intensified to a hurricane despite adverse conditions, with maximum sustained winds of nearly 60 mph — a fortuitous development because the HS3 team was able to once again capture the precursor conditions for intensification. By October 4, however, the meandering Nadine had breathed her last, dying in the northeastern Atlantic Ocean.

Big Success

The mission, Braun said, was an unqualified success. Altogether the mission racked up 150 flight hours and covered a total of about 50,000 nautical miles, including some flight time around the eastern side of Hurricane Leslie before the HS3 mission officially began.

The HS3 mission is far from over. In 2013 and 2014, the team plans to return, but this time with a second Global Hawk equipped with an additional three instruments, including the Goddard-developed High-Altitude Imaging Wind and Rain Profiler, to sample the internal structure of hurricanes.

By the time HS3 ends, the team hopes to have dramatically improved scientists' understanding of how storms intensify. "What we hope to do is take this technique and make it part of the operational forecast infrastructure," said Paul Newman, the HS3 deputy principal investigator. ❖

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Amino Acids, *continued from page 3*

Their discovery revolutionized the field of astrobiology, reigniting the question of whether life, as we know it, existed elsewhere in the solar system and beyond.

Amino acids, in part, hold the key to ultimately answering that question. They are the building blocks of proteins — the workhorse molecules of life, used in everything from creating hair and fingernails, to the enzymes that speed up or regulate chemical reactions inside cells. Just as the 26 letters of the alphabet are arranged in limitless combinations to make words, life uses 20 different amino acids in a huge variety of arrangements to build millions of different proteins.

Amino acids demonstrate another interesting characteristic. Although they come in two non-superimposable forms — left-handed and right-handed — only abiotic or non-biological organic compounds use both. The amino acids that give rise to life must have the same orientation or chirality, which means they use only one of the two available mirror images of the amino-acid structure.

Left-Handed Bias

Life on Earth got established with only the left-handed version, leading scientists to wonder whether this inclination arose because of random processes or whether meteorites may have seeded this propensity.

To find out, Getty's colleagues at the Goddard Astrobiology Analytical Laboratory have studied carbon-rich meteorites and tiny grains collected from the Wild 2 comet. They discovered an excess of the left-handed amino acids in some of the meteorite samples they studied, suggesting that left-handed amino acids got their start in space, where conditions in asteroids favored the creation of this particular orientation.

"Research shows that meteorites seeding the early Earth could have jump started left-handed-based protein in life as we know it today," said OASIS Co-Investigator Danny Glavin, a world-renowned expert in extraterrestrial organic chemistry. "They contributed these molecules that may have created an initial bias toward left-handedness."

The question is, does the bias exist on other solar system bodies, and if so, does it favor left- or right-handed amino acids? OASIS's ability to detect amino acids and determine their chirality — the ratio of left- to right-handed molecules — will be an important capability for ultimately answering that question, Glavin said.

OASIS's Unique Instrumentation

Scientists have used a technique called gas chromatography-mass spectrometry since the 1970s to study organic compounds. NASA first used the technique on the Viking Mission to Mars in 1976, but it failed to detect them due to problems with experiment design. It also is being used on the Goddard-developed Sample Analysis at Mars (SAM) instrument suite. Like the Viking version, SAM uses heat to process crushed rock samples. As they heat, the samples break down, releasing gases that SAM's gas chromatograph and mass spectrometer then measure to identify organic compounds in the samples.

Although effective, heat can fragment organic carbon, resulting in the loss of molecular information. To preserve those details, SAM features a "one-pot" solvent-extraction experiment that is gentler on the samples. Though the experiment is capable of detecting amino acids, it won't measure chirality, Getty said.

Photo Credit: Chris Gunn

This photo shows examples of four different lengths of the microchannel component that is at the core of Getty's "lab-on-a-chip" liquid chromatograph. The miniaturized instrument will help scientists analyze amino acids and measure their chirality.

Continued on page 15

Her team specifically is designing OASIS to provide that critical measurement. Instead of heat, the instrument uses liquid to prepare the samples and then separate and detect complex organic compounds, including amino acids.

"We have found that liquid chromatography, coupled with mass spectrometry, is the most sensitive and selective method for measuring amino acids in the laboratory," Glavin said. "OASIS is our first step towards the development of a miniaturized spaceflight instrument."

Breadboard Design

Under the ASTID instrument-development award, Getty's team is building a breadboard system equipped with an advanced miniaturized mass spectrometer originally developed for the Volatile Analysis by Pyrolysis of Regolith (VAPoR) instrument, which Glavin conceived for determining whether the large concentrations of hydrogen on the lunar poles were actually water ice deposited by comet bombardments (*Goddard Tech Trends*, Summer 2007, Page 2).

Among other technologies, it also will include a "lab-on-a-chip" liquid chromatograph, an instrument that — like Glavin's VAPoR — traces its heritage to previous Goddard Internal Research and Development (IRAD) program investments. "The real key is liquid chromatography," Getty said. "It will separate the sample according to chemical structure, giving us another dimension of data, another approach for teasing out details that would identify the compound."

Goal: Flight-Qualified Instrument

Ultimately, the team hopes to further miniaturize the breadboard to produce a low-mass, low-power, flight-qualified instrument weighing no more than 11 pounds. "These are lean times for planetary science," Getty said, "but it helped to have those four years of IRAD support to hone our message and mature the component-level technology. This instrument will be 100 times more sensitive, yet smaller and lighter weight than what we've flown so far." ❖

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Seeing the Forest, *continued from page 9*

"There's always been a big scientific question about how much carbon is in these forests, but it's also now a big policy question," Fatoyinbo-Agueh said.

But obtaining verifiable and consistent measurements is a challenge. By their very nature, these forests cover vast areas. They're often in remote locations that can be very difficult and even unsafe to visit to conduct on-the-ground research. "So it just seems far better to stay in the air," she said. With EcoSAR, she and her partner, Goddard engineer Rafael Rincon, will do just that.

EcoSAR Flies in 2013

The team plans to fly EcoSAR for the first time in 2013 aboard NASA's P-3 research aircraft. The first operational field campaign will take place a year later in Costa Rica.

This advanced airborne polarimetric and interferometric P-band radar traces its heritage to Rincon's L-Band Digital Beamforming Synthetic Aperture Radar. This technology demonstrated for the first time the ability to simultaneously synthesize and process multiple radar beams and produce high-resolution data over larger areas. In contrast, conventional radar systems gather high-resolution data only along a narrow swath.

EcoSAR adapts the same general approach, but focuses on the P-Band, a lower microwave frequency that can pierce forest canopies — from the tops of trees, down through the leaves, and to the ground — to obtain unprecedented two- and three-dimensional fine-scale measurements of biomass. The data measure the tree heights and the entire forest canopy.

Finding Lost Worlds

Ultimately, she would like to see a version of EcoSAR flying even higher and becoming a satellite instrument. But even before then, Fatoyinbo-Agueh hopes the airplane-based EcoSAR, once complete, will be used for a variety of other applications. "The P-band can penetrate one meter below ground, so you could use it for permafrost studies, because if you have ice underground, you could measure that," she said. "You could use it for ground topology, for measuring river basins, even for archeological studies like uncovering lost cites underneath forest canopies." ❖

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Mobile Instrument Passes Important Milestone

A patent-pending, suitcase-size instrument that scientists could deploy virtually anywhere to measure three important carbon-cycle gases has achieved an important milestone in its development.

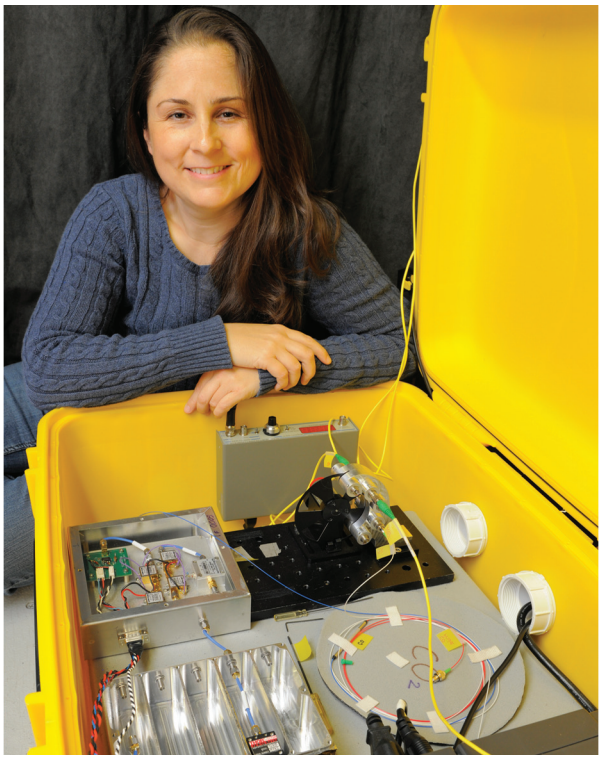
In September, Principal Investigator Emily Wilson Steel carried out a field campaign in Park Falls, Wisconsin, to demonstrate for the first time the mini-laser heterodyne radiometer (mini-LHR), an affordable, highly mobile instrument that measures the concentrations of carbon dioxide, methane, and carbon monoxide in the atmospheric column.

"The raw data looks great," Steel said. "We're officially past the initial-development stage. Now we're focusing on the retrieval algorithm that will calculate the column and extract altitude profiles."

While awaiting the award of her instrument patent, Steel said that she and her team are tweaking its design to further reduce its size and ruggedize its components. Ultimately, the goal is to license the technology to industry. Four companies already have expressed interest in commercializing the instrument, she said, adding that in addition to scientists, the instrument would be ideal for power companies and others who need to monitor carbon emissions.

The need for a turnkey, highly mobile instrument is unmistakable, Steel said. Currently, the only ground-based network that measures carbon dioxide and methane in the atmospheric column is the Total Carbon Column Observing Network (TCCON). However, only two of its 16 sites are in the U.S., including one facility in Wisconsin where Steel conducted her field campaign. TCCON's instruments can measure the largest range of trace gases, but the network is sparse due to instrument cost and size, she said.

Steel's instrument, developed with Goddard R&D funding, overcomes those disadvantages, she said. Packaged literally inside a suitcase, users could easily deploy the relatively inexpensive instrument anywhere in the world, including the Arctic, a region not covered by NASA's Orbiting



Carbon Observatory-2. Steel also believes the mini-LHR could be used to calibrate and validate space-based missions measuring greenhouse gases.

Just as exciting is its potential to give scientists a far more complete picture of carbon-cycle gases in the atmosphere. The new instrument works in tandem with the passive aerosol sensor currently used in NASA's AERONET, a Goddard-run network of more than 450 aerosol-monitoring instruments worldwide. Because her instrument piggybacks with AERONET, NASA could rapidly deploy the instrument to any of the network's sites.

"We're not trying to compete with the TCCON or other measurement approaches. We're simply providing a tool to carry out targeted measurements of some key species to fill in data gaps," she said. "With this instrument, I think we'll have plenty of customers." ❖

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Cutting edge Goddard's Emerging Technologies

CuttingEdge is published quarterly by the Office of the Chief Technologist at the Goddard Space Flight Center in Greenbelt, Md. Formerly known as *Goddard Tech Trends*, the publication describes the emerging, potentially transformative technologies that Goddard is pursuing to help NASA achieve its mission. For more information about Goddard technology, visit the website listed below or contact Chief Technologist Peter Hughes, *Peter.M.Hughes@nasa.gov*. If you wish to be placed on the publication's distribution list, contact Editor Lori Keesey, *ljkeesey@comcast.* NP-2007-10-853-GSFC (revised 10/12)